Infant Mortality in the United States: Trends, Differentials, and Projections, 1950 through 2010

Gopal K. Singh, PhD, and Stella M. Yu, ScD, MPH

A B S T R A C T

Objectives. This study examined long-term trends and differences in infant mortality in the United States from 1950 through 1991 according to race and ethnicity, education, family income, and cause of death. Forecasts are made through the year 2010.

Methods. Log-linear regression models were applied to data from the National Vital Statistics System, National Linked Birth and Infant Death files, the National Maternal and Infant Health Survey, the National Natality Survey, and the National Infant Mortality Survey to model and forecast infant mortality.

Results. Dramatic declines in the US infant mortality rate have occurred in the past 4 decades, largely as a result of declines in mortality from pneumonia and influenza, respiratory distress syndrome, prematurity and low birthweight, congenital anomalies, and accidents. Despite the overall reductions, however, substantial racial/ethnic, educational, and income differences in infant mortality still exist.

Conclusions. The long-term downward trend in US infant mortality has not benefited Blacks and Whites equally. The Black/White disparity in infant mortality has not only persisted but increased over time and is not expected to diminish in the near future. Educational inequalities have also widened, and racial disparities have generally increased across all educational levels. (*Am J Public Health.* 1995;85: 957–964)

Introduction

The significance of infant mortality as an important indicator of a nation's health status and well-being has been well documented in social and biomedical research.[1-3] Although the infant mortality rate in the United States has declined steadily since 1933,[4] it is consistently higher than that for many other industrialized countries. The pace of decline in the US infant mortality rate has not equaled that of other industrialized countries. In 1988, the United States ranked 23rd in the world in infant mortality; in 1960, it had ranked 12th internationally.[4,5]

The relatively unfavorable international standing of the United States in terms of infant mortality stems in large part from the substantial racial (Black/White) disparity in infant survival and associated socioeconomic inequality that have existed in the country for a long period.[6] Substantial differences in infant mortality among Whites, Blacks, and other racial/ethnic groups have been well documented.[7,8] Considerable differences in infant mortality have also been noted in terms of such important socioeconomic variables as education and family income.[9-11] Furthermore, long-term trends in US infant mortality decline have not been uniform for various socioeconomic and demographic subgroups of the population and causes of infant death.[6]

A comprehensive analysis of the past trends, present status, and future course of mortality among infants not only is vital for developing effective maternal and child health programs and policies but is crucial in the formulation of overall national health planning. However, no systematic effort has yet been made to bring together a discussion of long-term trends and differentials in US infant mortality and their future implications according to such key sociodemographic variables as race and ethnicity, education, family income, and cause of death.

The purpose of this paper is (1) to examine long-term trends and differentials in infant, neonatal, and postneonatal mortality in the United States from 1950 through 1991 by race and ethnicity, education, and family income; (2) to examine the extent of socioeconomic differentials over time in infant mortality; (3) to examine changes in the race-specific patterns of leading causes of death over time; and (4) to assess the implications of the past and recent trends for the future course of mortality by projecting mortality rates for infants to the year 2010.

Materials and Methods

To analyze trends and differentials in infant mortality, we used the following data sources: (1) the National Vital Statistics System (for the years 1950 through 1991), (2) the National Linked Birth and Infant Death data sets (1985 through 1987 birth cohorts), (3) the 1988 National Maternal and Infant Health Survey, and (4) the National Natality Survey and National Infant Mortality Survey (for the years 1964 through 1966).

Gopal K. Singh is with the National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Md. Stella M. Yu is with the Maternal and Child Health Bureau, Health Resources and Services Administration, Rockville, Md.

Requests for reprints should be sent to Gopal K. Singh, PhD, National Center for Health Statistics, Division of Vital Statistics, 6525 Belcrest Rd, Room 840, Hyattsville, MD 20782.

The death certificate information from the National Vital Statistics System was used to compute infant mortality rates over time by age, race/ethnicity, and cause of death. The vital statistics data, collected by the National Center for Health Statistics, are available annually in published form from 1900 to the present[7,12] and on public-use microdata computer tapes from 1968 to 1991.[13] We made use of both the published mortality data and the death records extracted from the computer data files. The natality component of the National Vital Statistics System provided the annual numbers of live births used as denominators for computing infant mortality rates.

To compute infant mortality rates for detailed racial and ethnic groups and by maternal educational attainment, we used the National Linked Birth and Infant Death data sets for the 1985, 1986, and 1987 birth cohorts.[14–16] These linked cohort files are more suitable than the vital statistics period files for examining differences in infant mortality rates by race/ethnicity and education for two reasons. First, infant mortality rates based on period natality and mortality files tend to systematically underestimate the rates for racial/ethnic groups other than Whites and Blacks.[12] Second, the period files, without the linkage of birth and infant death records, cannot produce estimates of infant mortality rates by maternal education.

Income differentials in infant mortality cannot be directly examined by means of the National Vital Statistics System or linked birth/infant death files. To examine such differentials, we used live birth and infant death samples of the 1988 National Maternal and Infant Health Survey.[17,18] Rates based on the survey were weighted in order to produce nationally representative infant mortality rates by family income.

To examine the extent to which socioeconomic differentials in infant mortality have changed over time, we used education- and income-specific data derived from the National Natality and National Infant Mortality Surveys of 1964 through 1966.[19]

To describe time trends in infant mortality, we assumed the mortality rate to be a log-linear function of time in which Y_t is the infant mortality rate for a specific age group in year t. The simple log-linear regression model may be specified as $Log_e Y_t = \alpha + \beta t$, where $Log_e Y_t$ is the natural logarithm of Y_t, α is the intercept, and β is the slope to be estimated. The

parameters in this model were estimated by means of the ordinary least squares method. Note that $100 \cdot [exp(\beta) - 1]$ measures the annual percentage change in the infant mortality rate, Y_t.[20]

The preceding equation was also used to forecast infant mortality rates between 1992 and 2010. Wherever applicable, the quantity $100 \cdot [exp(\beta) - 1]$ was used to summarize a particular time series by indicating the average annual percentage change. Furthermore, between any two given time points, the percentage change in infant mortality rates by sociodemographic characteristics was computed by assuming a constant arithmetic change. Race differentials in infant mortality were measured by corresponding rate ratios. Whenever appropriate, pairwise differences in rate ratios between race and ethnic groups were tested for statistical significance.[8,11,21]

Results

Overall Trends in Infant Mortality

The infant mortality rate in the United States showed a consistent downward trend between 1950 and 1991. The decline in the rate during this period was quite impressive, with the average decline being 3.11% per year. However, the rate of decline was rather modest during 1950 through 1965 (only 1.03% per year). The rate fell sharply from 1966 through 1981, showing an approximately 50% reduction in that period. If one were to consider the provisional infant mortality rates of 8.5 and 8.3, respectively, for 1992 and 1993,[22] the average annual rate of decline between 1982 and 1993 would be 2.80%, which is not as dramatic as that for the previous period but is quite significant nonetheless.

Trends in Infant Mortality by Race

The rate of decline in infant mortality during 1950 through 1991 differed significantly for Black and White infants. The infant mortality rate for White infants during this period declined by 3.23% per year, while the rate for Black infants dropped by 2.89% annually. As a result, the racial disparity in the infant mortality rate increased between 1950 and 1991, even though there were periodic convergences during the late 1960s and mid-1970s. In 1950, the rate was 43.9 deaths per 1000 live births for Black infants, about 64% higher than the rate (26.8) for White infants. By 1991, the relative infant mortality situation for Black infants had deteriorated, with their rate of 16.5 being

2.2 times greater than the rate (7.5) for White infants. (For the sake of brevity, we do not present here the yearly race-specific infant mortality rates; they are, however, available from the authors.)

Trends in Neonatal and Postneonatal Mortality by Race

Neonatal mortality refers to infant deaths that occur during the first 27 days of life, while postneonatal mortality refers to infant deaths between 28 days and 1 year of age. Figure 1 shows trends in neonatal mortality rates and postneonatal mortality rates per 1000 live births in the United States during 1950 through 1991 for Whites and Blacks separately.

Between 1950 and 1991, neonatal mortality declined much faster than postneonatal mortality for the total population. The average annual percentage decreases were 3.41 for the neonatal mortality rate and 2.46 for the postneonatal mortality rate. As a result of this difference in the pace of decline, the relative contributions of neonatal and postneonatal mortality to overall infant mortality changed from 70% and 30% in 1950 to about 62% and 38% in 1991, respectively.
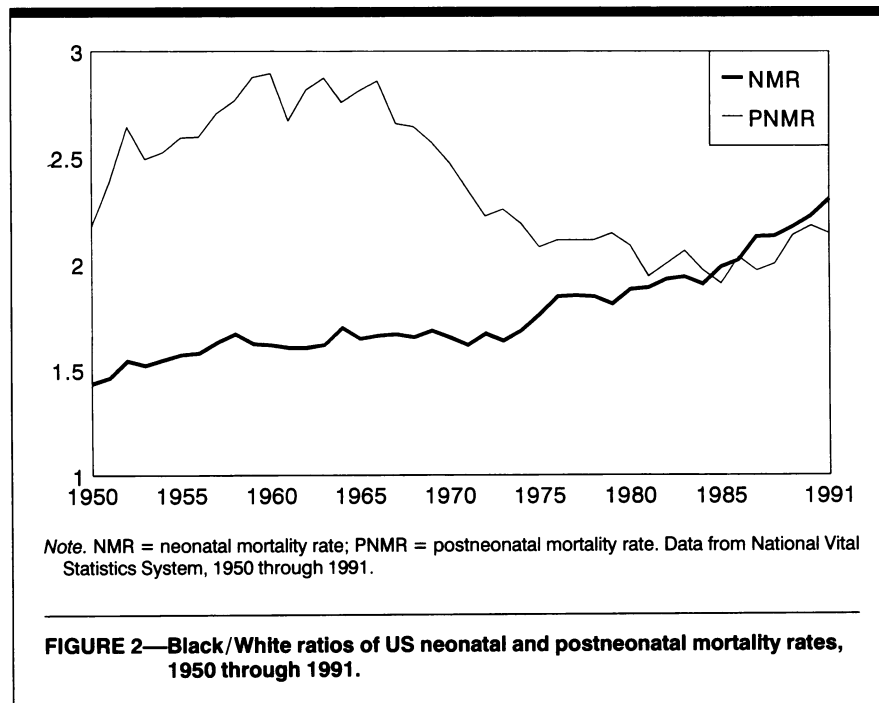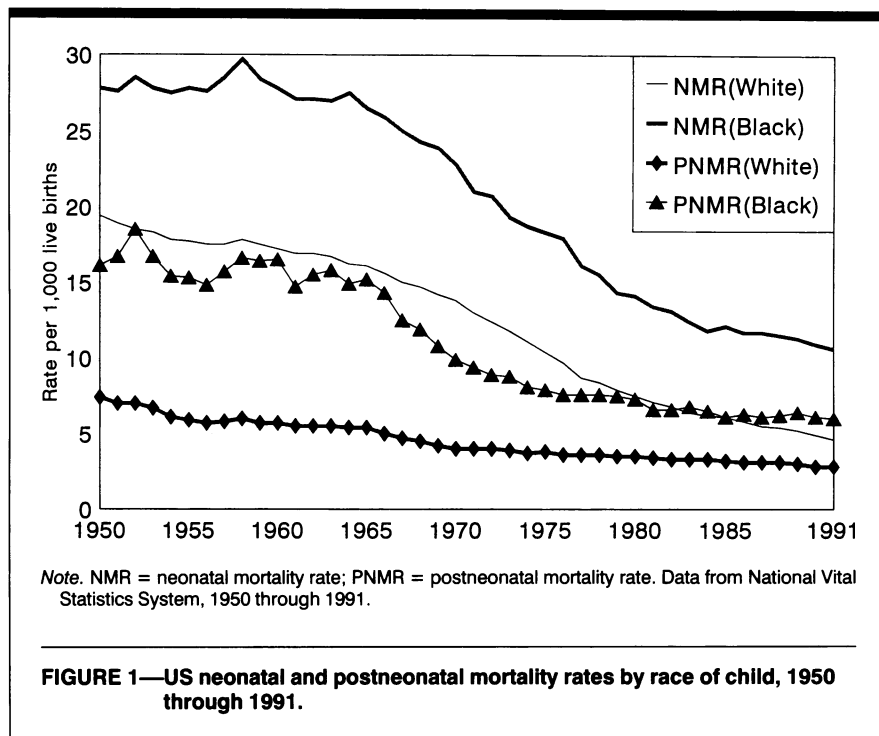
The trends in neonatal and postneonatal mortality by race reveal some interesting patterns. As for the total population, the neonatal mortality rate declined at a considerably faster pace than the postneonatal mortality rate for White infants; the average annual percentage decreases were 3.65 for the neonatal rate and 2.27 for the postneonatal rate. For Black infants, however, the reverse was true; their postneonatal mortality during 1950 through 1991 showed a more rapid decline than their neonatal mortality, with the respective average annual percentage decreases being 3.09 and 2.78. These racial differences in rates of decline of neonatal and postneonatal mortality had significant implications for racial disparities in neonatal and postneonatal mortality over time. Like infant mortality, neonatal mortality has seen an increasing racial inequality over time; Black infants had a 43% higher risk of dying than White infants in the neonatal period in 1950, in comparison with a 130% higher risk in 1991. Postneonatal mortality, on the other hand, has seen a narrowing of Black–White differentials, especially in the last 30 years or so. For instance, in 1960 Black infants were 2.9 times more likely than White infants to die in the postneonatal period; in 1991 their relative postneonatal mortality risk was 2.1 times that of Whites (see Figure 2).

Race and Ethnic Differences in Infant, Neonatal, and Postneonatal Mortality

We have thus far focused only on differences between Whites and Blacks. Substantial differences in infant mortality, neonatal mortality, and postneonatal mortality rates also exist among various other race and ethnic groups, the reliable data for whom are available only from the National Linked Birth and Infant Death records. Table 1 shows neonatal and postneonatal rates for Whites, Blacks, and such ethnic groups as American Indians, Chinese, Japanese, Filipinos, Hawaiians, other Asian and Pacific Islanders, Mexicans, Puerto Ricans, Cubans, Central and South Americans, and other Hispanics. The other Asian and Pacific Islanders category comprises Asian Indians, Koreans, Vietnamese, Cambodians, Laotians, Indonesians, Pakistanis, Bangladeshis, Sri Lankans, and other Asian or Pacific Islanders.[8]

Before a discussion of the race and ethnic differentials in Table 1, it is important to note that, unlike in Figure 1, infant deaths and live births in Table 1 were classified according to maternal race/ethnicity. Three years of aggregate data are presented in Table 1 in order to provide stable estimates of mortality rates for American Indians, Asian and Pacific Islanders, and Hispanic Americans.

The data in Table 1 show that the infant mortality rate (the sum of the neonatal and postneonatal mortality rates) was substantially lower for Chinese and Japanese than for any other group. In comparison with White infants, Chinese, Japanese, and Filipino infants had 30%, 23%, and 16% lower infant mortality rates, respectively. Cuban, Central and South American, and Mexican infants also had significantly lower rates than White infants. However, Puerto Rican, Hawaiian, American Indian, and Black infants fared much more poorly in their mortality, with their respective rates being 26%, 33%, 55%, and 112% higher than that for White infants. Similar ethnic differences were found in neonatal mortality, with Chinese, Japanese, Filipinos, Mexicans, and Central and South Americans showing significantly lower risks of neonatal death than Whites; Blacks, Puerto Ricans, Hawaiians, and American Indians had significantly higher risks. As for postneonatal mortality, Cubans and Filipinos had the lowest rates, while American Indians, Blacks, and Hawaiians had the highest rates. In comparison with

Note. NMR = neonatal mortality rate; PNMR = postneonatal mortality rate. Data from National Vital Statistics System, 1950 through 1991.

FIGURE 1—US neonatal and postneonatal mortality rates by race of child, 1950 through 1991.

Note. NMR = neonatal mortality rate; PNMR = postneonatal mortality rate. Data from National Vital Statistics System, 1950 through 1991.

FIGURE 2—Black/White ratios of US neonatal and postneonatal mortality rates, 1950 through 1991.

the postneonatal rate for Whites, the rate was 2.3 times higher for American Indians and 2 times higher for Blacks; on the other hand, the rate was 29% lower for Cubans than for Whites.

Trends and Differences in Infant Mortality by Maternal Education

Table 2 presents race differentials in infant mortality by maternal education at two time points: 1964 through 1966 and 1987. The 1964 through 1966 data in Table 2 were adapted directly from the 1971 study by MacMahon et al.[19] Generally, maternal education seemed to be inversely associated with infant mortality for both time periods, although a much stronger and consistent educational gradient in infant mortality could be noted for both Whites and Blacks in the latter

TABLE 1—US Neonatal and Postneonatal Mortality Rates (NMR and PMR) and Cause-Specific Infant Mortality Rates per 1000 Live Births, by Maternal Race or Ethnicity, 1985 through 1987

| Race/Ethnicity | NMR | PMR | Cause of Death[a] | | | | No. of Live Births |
			Perinatal Conditions	Congenital Anomalies	SIDS	Other Causes	
White[b]	5.5	3.1	3.8	2.1	1.2	1.5	1 814 669
Black	12.0	6.2	10.1	2.3	2.3	3.5	1 782 007
American Indian	6.1	7.2	4.0	2.4	3.2	3.7	103 191
Asian and Pacific Islander	4.7	2.9	3.1	2.0	1.0	1.5	327 178
Chinese	3.4	2.6	2.2	1.6	0.9	1.2	50 572
Japanese	3.9	2.7	2.6	1.7	1.3	1.0	23 919
Filipino	4.7	2.5	2.9	2.1	0.9	1.3	63 060
Other Asian[c]	5.0	3.1	3.3	2.2	0.9	1.6	174 479
Hawaiian	7.1	4.3	5.0	2.2	1.9	2.2	15 148
Hispanic[d]	5.5	3.0	3.9	2.1	0.8	1.7	1 168 084
Mexican	5.2	2.9	3.6	2.1	0.8	1.7	740 382
Puerto Rican	7.3	3.7	5.7	2.1	1.0	2.1	109 874
Cuban	5.5	2.2	3.8	1.9	0.8	1.3	29 935
Central and South American	5.2	2.6	3.8	2.0	0.5	1.5	136 367
Other and unknown Hispanic	5.7	3.4	3.9	2.3	1.2	1.7	151 526

Source. Data are from the National Linked Birth and Infant Death data sets, 1985–1987.
[a]ICD-9 codes 760–779 (perinatal conditions), 740–759 (congenital anomalies), and 798.0 (sudden infant death syndrome [SIDS]).
[b]Based on a 20% sample of live births.
[c]Includes Asian Indians, Koreans, Vietnamese, Cambodians, Laotians, Indonesians, and other Asian and Pacific Islanders.
[d]Based on data from 23 reporting states and the District of Columbia.

TABLE 2—US Infant Mortality Rates per 1000 Live Births, by Maternal Education and Race, 1964 through 1966 and 1987

Maternal Education, y	White	Black	Black/ White Ratio
1964–1966[a]			
0–8	32.0	45.9	1.4
9–11	24.6	41.7	1.7
12	18.0	34.5	1.9
13–15	15.0	32.1	2.1
16+	19.6	...	...
All levels	20.8	39.5	1.9
1987[b]			
0–8	12.5	21.6	1.7
9–11	12.4	20.0	1.6
12	8.1	16.6	2.0
13–15	6.4	14.7	2.3
16+	5.8	13.3	2.3
All levels	8.3	17.8	2.1

[a]Data from National Natality Survey and National Infant Mortality Survey, 1964–1966.
[b]Data from National Linked Birth and Infant Death data set, 1987 birth cohort.

period. Specifically, infant mortality rates in 1964 through 1966 for Black infants declined consistently with increasing levels of maternal education, while rates for White infants declined sharply with increasing maternal education until 12 years but then leveled off for the three highest educational categories. In 1987, rates decreased consistently with increasing levels of maternal education for both White and Black infants, but the effect of maternal education on infant mortality appeared to be greater for White than for Black infants.

In both 1964 through 1966 and 1987, Black infants had significantly higher infant mortality rates than White infants at all levels of maternal education. However, the race ratios in Table 2 indicate that the Black–White disparity was greater at higher levels of education and that the racial disparity had generally increased across all educational levels during 1964 through 1987.

Between 1964 and 1987, infant mortality fell substantially across all educa-

tional strata for both Whites and Blacks, although infants born to mothers with 16 or more years of education showed the largest percentage decline in their mortality rates. The group of infants that benefited the least in terms of improved survival to 1 year of age were those born to mothers with 9 to 11 years of education. These differential changes in infant mortality rates by maternal education have produced increasing educational inequality (measured as the ratio of rates between the lowest and highest educational groups) over time, and such inequality appeared to be more pronounced among Whites than among Blacks.

Trends and Differences in Infant Mortality by Family Income

Table 3 shows race differentials in infant mortality by family or household income in 1964 through 1966 and 1987. Before a discussion of the income differentials, two brief comments on the comparability of income categories for the two time periods are in order. First, for the

1964 through 1966 surveys, data were available on family income; however, data were available on household income rather than family income for the 1988 National Maternal and Infant Health Survey. Thus, household and family incomes were assumed to be about the same in order to facilitate the analysis of trends in income differentials. Second, the income categories for 1988 were developed to roughly approximate the respective income categories for 1964 through 1966 by taking into account the values of the consumer price index for these years.[23] The consumer price index adjustment values were then applied to the 1964 through 1966 income categories (e.g., less than $3000 in 1964 through 1966 was roughly equivalent to less than $10 000 in 1988, $3000 to $4999 in 1964 through 1966 was roughly equivalent to $10 000 to $17 999 in 1988, and so on).

Income differentials in infant mortality rates in Table 3 revealed a pattern somewhat similar to that observed for educational differences. Like educational attainment, family income in general was inversely related to infant mortality rate. The inverse income and infant mortality relationship tended to be more consistent and pronounced for the latter time period

TABLE 3—US Infant Mortality Rates per 1000 Live Births, by Family or Household Income and Race, 1964 through 1966 and 1988

Income, $	White	Black	Black/White Ratio
1964–1966ᵃ			
<3000	27.3	42.5	1.6
3000–4999	22.1	46.8	2.1
5000–6999	17.8	22.0	1.2
7000–9999	19.2	37.6	2.0
10 000+	19.4	31.5	1.6
All	20.8	39.5	1.9
1988ᵇ			
<10 000	11.2	19.3	1.7
10 000–17 999	9.5	18.5	1.9
18 000–24 999	7.7	16.1	2.1
25 000–34 999	7.3	14.6	2.0
35 000+	7.2	16.6	2.3
All	8.3	18.1	2.2

Note. Figures for 1964–1966 are based on family income; figures for 1988 are based on household income.
ᵃData from National Natality Survey and National Infant Mortality Survey, 1964–1966.
ᵇData from National Maternal and Infant Health Survey, 1988.

TABLE 4—US Infant Deaths and Mortality Rates per 100 000 Live Births, by Race, and Mortality Race Ratios for the 10 Leading Causes of Infant Death, 1991 and 1981

Cause of Death (ICD-9 Code[s])	No. White	No. Black	Rate White	Rate Black	Black/White Ratio
1991					
Congenital anomalies (740–759)	5 864	1 524	184.7	210.2	1.1
Sudden infant death syndrome (798.0)	3 572	1 589	112.5	219.1	1.9
Disorders related to short gestation and unspecified low birthweight (765)	2 097	1 957	66.1	269.9	4.1
Respiratory distress syndrome (769)	1 622	898	51.1	123.8	2.4
Newborn affected by maternal complications of pregnancy (761)	988	519	31.1	71.6	2.3
Newborn affected by complications of placenta, cord, and membranes (762)	643	290	20.3	40.0	2.0
Accidents and adverse effects (E800–E949)	638	276	20.1	38.1	1.9
Infections specific to the perinatal period (771)	556	304	17.5	41.9	2.4
Pneumonia and influenza (480–487)	346	234	10.9	32.3	3.0
Intrauterine hypoxia and birth asphyxia (768)	397	190	12.5	26.2	2.1
All causes	23 657	11 994	745.3	1 654.0	2.2
1981					
Congenital anomalies (740–759)	7 224	1 443	248.4	245.5	1.0
Sudden infant death syndrome (798.0)	3 676	1 462	126.4	248.7	2.0
Disorders related to short gestation and unspecified low birthweight (765)	2 126	1 460	73.1	248.4	3.4
Respiratory distress syndrome (769)	3 194	1 050	109.8	178.6	1.6
Newborn affected by maternal complications of pregnancy (761)	959	469	33.0	79.8	2.4
Newborn affected by complications of placenta, cord, and membranes (762)	739	233	25.4	37.9	1.5
Accidents and adverse effects (E800–E949)	689	259	23.7	44.1	1.9
Infections specific to the perinatal period (771)	642	236	22.1	40.1	1.8
Pneumonia and influenza (480–487)	507	274	17.4	46.6	2.7
Intrauterine hypoxia and birth asphyxia (768)	954	416	32.8	70.8	2.2
All causes	30 478	11 757	1 047.8	2 000.2	1.9

Note. Infant deaths are based on race of decedent, while live births are based on race of child.
Source. Data are from the National Vital Statistics System, 1981–1991.

than for the earlier period and for White infants than for Black infants. Specifically, the rate associated with a family income of less than $10 000 in 1988 was almost twice as large as that associated with a family income of $35 000 or more. In addition, the difference between the lowest and highest income brackets in 1988 was wider for Whites than for Blacks.

No significant evidence was found for an increased income inequality for either of the two racial groups. However, the racial disparity in infant mortality appeared to have increased between 1964 and 1988 for the middle income ($18 000 to $24 999) and highest income ($35 000+) categories.

Leading Causes of Infant Mortality

Infant deaths and mortality rates associated with the 10 leading causes of infant death in 1991 are shown in Table 4. These cause-of-death data were based on deaths from underlying causes rather than multiple causes and were coded according to the *International Classification of Diseases,* 9th Revision (ICD-9). Congenital anomalies were the leading cause of infant death for the total population in

1991, accounting for one of every five infant deaths. The second, third, and fourth leading causes for the total population were sudden infant death syndrome, prematurity and low birthweight, and respiratory distress syndrome, which re-

spectively accounted for 14.5%, 11.3%, and 7% of all infant deaths in 1991. Maternal complications of pregnancy; complications of placenta, cord, and membranes; accidents (unintentional injuries); perinatal infections; pneumonia and influ-

TABLE 5—US Infant Mortality Rate per 100 000 Live Births for Selected Major Causes of Death, 1960 through 1991

Year	Congenital Anomalies	Sudden Infant Death Syndrome	Respiratory Distress Syndrome	Short Gestation and Low Birthweight	Accidents and Adverse Effects	Pneumonia and Influenza
1960	361.4	...	...	457.0	90.0	314.1
1961	363.5	...	...	435.7	83.9	298.5
1962	355.9	...	...	429.7	87.7	296.0
1963	355.8	...	...	409.2	85.7	295.1
1964	352.5	...	...	396.6	84.6	283.5
1965	357.5	...	...	383.8	88.2	287.4
1966	338.3	...	...	366.8	85.9	261.7
1967	330.4	...	...	338.2	78.1	225.4
1968	315.6	...	236.1	269.1	72.0	225.8
1969	314.1	...	247.9	248.5	67.4	198.4
1970	301.7	...	261.6	234.6	61.5	168.9
1971	299.8	...	267.6	207.7	63.3	151.9
1972	290.3	...	274.7	191.2	54.8	132.9
1973	285.4	104.0	272.8	171.2	53.9	113.5
1974	272.4	119.5	263.4	149.3	46.0	82.7
1975	272.9	133.0	248.0	139.9	42.5	70.0
1976	263.4	137.5	222.9	125.5	39.6	61.9
1977	253.1	142.8	198.3	111.6	35.3	50.6
1978	252.1	148.9	179.7	110.3	37.9	46.0
1979	255.4	151.1	165.2	100.0	30.9	32.3
1980	255.2	152.5	138.1	101.0	32.3	28.0
1981	245.6	145.9	119.0	100.8	27.0	22.3
1982	245.2	143.4	109.7	98.3	27.8	20.5
1983	240.0	145.8	101.2	91.6	26.3	21.1
1984	233.0	142.9	96.9	88.9	22.8	18.7
1985	227.7	141.3	98.2	86.6	23.7	18.7
1986	219.5	140.5	90.6	86.4	24.2	17.6
1987	207.0	137.3	86.2	88.0	24.9	17.7
1988	208.2	140.1	81.4	83.6	23.9	16.4
1989	200.9	139.4	89.9	97.3	24.6	15.7
1990	198.1	130.3	68.5	96.5	22.4	15.2
1991	186.9	130.1	62.5	100.7	23.4	14.8

Source. Data are from the National Vital Statistics System, 1960–1991.

Race and Ethnic Differences in Cause-Specific Infant Mortality

Black infants had higher mortality rates than White infants for each of the 10 leading causes of death in both 1981 and 1991. However, the Black/White ratios of infant mortality from prematurity and low birthweight, pneumonia and influenza, and perinatal infections increased during 1981 through 1991, thus exacerbating the already-substantial racial disparity in mortality from these causes (see Table 4).

To describe ethnic differences in cause-specific infant mortality, we briefly return to Table 1, which contains cohort-specific infant mortality rates per 1000 live births. Three cause-of-death categories are considered: congenital anomalies, sudden infant death syndrome, and an aggregate category of perinatal conditions (which may relate to pregnancy, labor and delivery, slow growth of the fetus, or birth trauma). In comparison with White infants, Chinese, Japanese, and Filipino infants were significantly less likely to die from perinatal conditions. Black, Puerto Rican, and Hawaiian infants, on the other hand, were 2.7, 1.5, and 1.3 times more likely to die from perinatal conditions than White infants, respectively. Ethnic differentials in congenital anomalies were rather small, with only American Indian babies dying from this cause at a somewhat higher rate than other race/ethnic groups. Of all groups, American Indian infants were at the highest risk of dying from sudden infant death syndrome; their mortality risk was 2.7 times greater than that for White infants. The risk of dying from sudden infant death syndrome was about 2 times greater for Black than for White infants. Among Asian and Pacific Islanders, Hawaiian and, surprisingly, Japanese infants showed higher mortality rates from sudden infant death syndrome than their other Asian and White counterparts. Hispanic infants had the lowest risk of mortality from sudden infant death syndrome, with Central and South Americans, in particular, having less than half the risk estimated for Whites.

Trends in Major Causes of Infant Mortality

Table 5 shows trends in yearly mortality rates for six major causes of infant death from 1960 through 1991. Before an attempt is made to analyze these time trends in Table 5, it should be emphasized that there were significant comparability breaks (i.e., classification changes) in the ICD for respiratory distress syndrome

enza; and intrauterine hypoxia and birth asphyxia rounded out the top 10 causes of infant death in 1991.

The first and third leading causes of death in 1991 were different for White and Black infants. Congenital anomalies were the leading cause of infant death among White infants and the third leading cause among Black infants. Prematurity and low birthweight, the third leading cause of death among White infants, was the leading cause of death among Black infants and accounted for one in every six Black infant deaths in 1991. Sudden infant death syndrome remained the second major killer of both White and Black babies.

Table 4 also shows infant deaths and mortality rates by race in 1981 for the same 10 causes that were the 10 leading causes of death in 1991. The top 5 causes for the total population were the same as those in 1991, with respiratory distress syndrome being the third leading cause

and prematurity and low birthweight the fourth leading cause of infant death. While congenital anomalies were the leading cause of death for White infants in 1981, sudden infant death syndrome was the No. 1 cause of death among Black infants. However, in that year, prematurity and low birthweight accounted for almost as many Black infant deaths as sudden infant death syndrome.

A comparison of infant mortality rates for the leading causes of death in Table 4 reveals that, between 1981 and 1991, the greatest mortality decline in causes of infant death occurred for intrauterine hypoxia and birth asphyxia, respiratory distress syndrome, and pneumonia and influenza. The declines in these causes were shared by both White and Black infants. However, a disconcerting trend emerged for Black infants, whose mortality from prematurity and low birthweight increased by almost 9% during 1981 through 1991.

(between the 8th and 9th revisions of the ICD), for short gestation and low birthweight (between the 8th and 9th revisions and the 7th and 8th revisions), for accidents (between the 8th and 9th revisions and the 7th and 8th revisions), and for pneumonia and influenza (between the 8th and 9th revisions and the 7th and 8th revisions). Mortality from congenital anomalies and sudden infant death syndrome was, however, quite comparable across different ICD revisions. Comparability ratios between different ICD revisions for these causes of infant death, provided by MacDorman and Rosenberg,[4] were applied to cause-specific infant mortality rates before the regression-based average annual percentage changes in rates were computed.

Infant mortality from congenital anomalies (birth defects) and pneumonia and influenza showed a consistently downward trend throughout the 31-year period, although mortality from pneumonia and influenza declined at a much faster pace (see Table 5); the average annual percentage declines in mortality were 2.1% for congenital anomalies and 10.5% for pneumonia and influenza. Infant mortality from prematurity and low birthweight also fell rapidly in a fairly consistent manner until 1988, with an average rate of decline of 5.4% per year. Respiratory distress syndrome mortality showed a rapid downward trend between 1972 and 1991, with the decrease occurring at an average rate of slightly more than 7% per year. Infant mortality from accidents also went down substantially during 1960 through 1984; since 1985, the rate has more or less stabilized. The average annual percentage decrease during 1960 through 1991 in accident mortality was 4.7. Mortality from sudden infant death syndrome rose substantially from 1973 through 1979; since 1980, however, it has decreased at an average rate of 1.1% per year. The increase in sudden infant death syndrome mortality during 1973 through 1979 has been attributed to changes in diagnostic terminology and has not been interpreted as a real increase in mortality.[4]

Projection of Infant Mortality Rates to the Year 2010

Table 6 presents forecasts of infant mortality based on simple log-linear regression models. In making the forecasts, we assumed that the proportionate declines in annual infant mortality rates were constant during 1950 through 1991 and that the rates would continue to decline at the same log-linear rates as they

had in that period. It should be kept in mind that the forecasts we present here are purely extrapolative; no provisions are made for likely social, demographic, political, behavioral, medical, or technological influences on future mortality changes.

Table 6 shows projected neonatal and postneonatal mortality rates from 1992 to 2010 for White and Black infants. If the past trends were to continue, we would expect an infant mortality rate of 7.0 per 1000 live births by the year 2000, meeting exactly the year 2000 goal set by the US Department of Health and Human Services.[24] However, the Black rate would fall well short of the year 2000 target of 11.0. Moreover, while the projected postneonatal mortality rate (4.1) for Black infants in the year 2000 is close to that targeted by Healthy People 2000,[24] the projected neonatal mortality rate (8.6) for Black infants is expected to fall significantly short of the goal of 7.0. (A more complete set of projections of infant, neonatal, and postneonatal mortality rates for the total population is available from the authors.)

An interesting implication of the past trends in infant, neonatal, and postneonatal mortality is that the Black/White disparity is not expected to diminish over the next 18 years or so; rather, it should gradually reach the ratio of 2.2 attained in 1991. If past trends are an indication of what is to come, one would expect the racial disparity in neonatal mortality to

grow and that in postneonatal mortality to diminish.

Discussion

The past 4 decades have witnessed dramatic declines in the US infant mortality rate, largely as a result of considerable declines in mortality from such major causes as pneumonia and influenza, respiratory distress syndrome, prematurity and low birthweight, congenital anomalies, and accidents. However, despite the impressive reductions in overall infant mortality, the race (Black/White) disparity in infant mortality not only has persisted but has increased over time and, unfortunately, is not expected to diminish in the near future. The risk of mortality is currently 2.2 times higher for Black infants than for White infants, a ratio that is projected to prevail during the first decade of the 21st century.

The findings of this study also indicate substantial differences in the US infant mortality rate across other race and ethnic groups, such as American Indians, Chinese, Japanese, Filipinos, Hawaiians, other Asian and Pacific Islanders, Mexicans, Puerto Ricans, Cubans, Central and South Americans, and other Hispanics. While Chinese, Japanese, and Filipinos exhibit the lowest infant mortality rates, Hawaiians and American Indians show significantly higher rates than Whites but lower rates than Blacks. Among Hispan-

TABLE 6—Projected US Neonatal and Postneonatal Mortality Rates per 1000 Live Births, by Race of Child, 1992 through 2010

Year	Neonatal Mortality Rate			Postneonatal Mortality Rate		
	White	Black	Black/White Ratio	White	Black	Black/White Ratio
1992	5.1	10.7	2.10	2.7	5.2	1.96
1993	4.9	10.4	2.12	2.6	5.1	1.94
1994	4.7	10.1	2.14	2.6	4.9	1.93
1995	4.6	9.9	2.16	2.5	4.8	1.91
1996	4.4	9.6	2.18	2.4	4.6	1.89
1997	4.2	9.3	2.20	2.4	4.5	1.88
1998	4.1	9.1	2.22	2.3	4.3	1.86
1999	3.9	8.8	2.24	2.3	4.2	1.85
2000	3.8	8.6	2.26	2.2	4.1	1.83
2001	3.7	8.3	2.28	2.2	4.0	1.82
2002	3.5	8.1	2.30	2.1	3.8	1.80
2003	3.4	7.9	2.32	2.1	3.7	1.79
2004	3.3	7.7	2.34	2.0	3.6	1.77
2005	3.1	7.4	2.36	2.0	3.5	1.76
2006	3.0	7.2	2.38	1.9	3.4	1.74
2007	2.9	7.0	2.41	1.9	3.3	1.73
2008	2.8	6.8	2.43	1.9	3.2	1.71
2009	2.7	6.6	2.45	1.8	3.1	1.70
2010	2.6	6.5	2.47	1.8	3.0	1.68

ics, Cubans have the lowest infant mortality rate, while Puerto Rican infants, in particular, experience a relatively increased risk of death.

Marked differences in infant mortality also exist by education and family income. This study provides strong evidence that the educational inequality in infant survival widened between 1964 and 1987, a finding similar to that reported for general mortality in the population 25 years of age and older.[25] During the same period, the Black/White disparity in infant mortality also appeared to increase across all educational levels. However, no empirical evidence was found in support of increasing income inequality in infant mortality.

In spite of the remarkable success achieved in improving overall maternal and child health in the past 4 decades, the United States has not made sufficient progress toward meeting several of the maternal and child health objectives outlined in *Healthy People 2000.*[26] The infant mortality rate in the United States remains higher than that in most other Western industrialized nations, perhaps largely as a result of the excess mortality observed among certain minorities and low socioeconomic status groups. There is little doubt that, as long as there are significant differences in the probability of survival among various racial/ethnic and socioeconomic groups, the potential for further improvements in US infant mortality rates exists. □

References

1. Centers for Disease Control. Consensus set of health status indicators for the general assessment of community health status—United States. *MMWR.* 1991;40: 449–451.
2. Klein RJ, Hawk SA. *Statistical Notes: Health Status Indicators: Definitions and National Data.* Hyattsville, Md: Public Health Service; 1992;1.
3. Nersesian WS. Infant mortality in socially vulnerable populations. *Annu Rev Public Health.* 1988;9:361–377.
4. MacDorman MF, Rosenberg HM. Trends in infant mortality by cause of death and other characteristics. *Vital Health Stat* 1993;1. DHHS publication PHS 93-1857.
5. *Health, United States, 1991.* Hyattsville, Md: Public Health Service; 1992. DHHS publication PHS 92-1232.
6. Zopf PE Jr. *Mortality Patterns and Trends in the United States.* Westport, Conn: Greenwood Press; 1992.
7. National Center for Health Statistics. Advance report of final mortality statistics, 1991. *Month Vital Stat Rep.* 1993;42(2) (suppl).
8. Singh GK, Yu SM. Pregnancy outcomes among Asian Americans. *Asian Am Pacific Islander J Health.* 1993;1:63–78.
9. Kitagawa EM, Hauser PM. *Differential Mortality in the United States: A Study in Socioeconomic Epidemiology.* Cambridge, Mass: Harvard University Press; 1973.
10. Singh GK, Rosenberg HM. Substance abuse and infant mortality in the United States: results from the 1988 National Maternal and Infant Health Survey. In: *Proceedings of the American Statistical Association, Social Statistics Section.* Alexandria, Va: American Statistical Association; 1992: 215–221.
11. Singh GK, Kposowa AJ. A comparative analysis of infant mortality in major Ohio cities: significance of socio-biological factors. *Appl Behav Sci Rev.* 1994;2:77–94.
12. *Vital Statistics of the United States, 1989, Volume II, Mortality, Part A.* Hyattsville,

Md: National Center for Health Statistics; 1993. DHHS publication PHS 93-1101.
13. *Catalog of Electronic Data Products.* Hyattsville, Md: Public Health Service; 1992.
14. *Linked Birth/Infant Death Data Set: 1985 Birth Cohort, Public Use Data Tape Documentation.* Hyattsville, Md: Public Health Service, 1990.
15. *Linked Birth/Infant Death Data Set: 1986 Birth Cohort, Public Use Data Tape Documentation.* Hyattsville, Md: Public Health Service; 1991.
16. *Linked Birth/Infant Death Data Set: 1987 Birth Cohort, Public Use Data Tape Documentation.* Hyattsville, Md: Public Health Service; 1992.
17. *1988 National Maternal and Infant Health Survey: Public Use Data Tape Documentation.* Hyattsville, Md: Public Health Service; 1991.
18. Sanderson M, Placek PJ, Keppel KG. The 1988 National Maternal and Infant Health Survey: design, content, and data availability. *Birth.* 1991;18:26–32.
19. MacMahon B, Kovar MG, Feldman JJ. Infant mortality rates: socioeconomic factors, United States. *Vital Health Stat.* 1972;22. DHEW publication HSM 72-1045.
20. Kleinman JC. State trends in infant mortality, 1968–83. *Am J Public Health.* 1986;76: 681–687.
21. Kleinman JC. *Statistical Notes: Infant Mortality.* Hyattsville, Md: Public Health Service; 1991;1.
22. National Center for Health Statistics. Births, marriages, divorces, and deaths for January 1994. *Month Vital Stat Rep.* 1994; 43(1).
23. *Statistical Abstract of the United States: 1993.* Washington, DC: US Bureau of the Census; 1993.
24. *Healthy People 2000: National Health Promotion and Disease Prevention Objectives.* Washington, DC: US Dept of Health and Human Services; 1990. DHHS publication PHS 91-50212.
25. Pappas G, Queen S, Hadden W, Fisher G. The increasing disparity in mortality between socioeconomic groups in the United States, 1960 and 1986. *N Engl J Med.* 1993;329:103–109.
26. *Healthy People 2000 Review, 1992.* Hyattsville, Md: Public Health Service; 1993.